FINAL REPORT

for

PROTOTYPE NICKEL CADMIUM CELLS FOR A FUTURE METEOROLOGICAL SPACECRAFT

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PROTOTYPE NICKEL CADMIUM CELLS FOR A FUTURE METEOROLOGICAL SPACECRAFT

by

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SUMMARY

The object of this report is to summarize the work accomplished during a program initiated to design and develop a prototype nickel-cadmium cell for a future meteorological satellite.

A cell, consisting primarily of thin plates to enhance charge characteristics, was developed, manufactured, and tested. A total of 265 cells were fabricated, of which 15 had rubber seals.

It was concluded that the desired characteristics of high rate (C/8) overcharge capability was achieved, but the differential between this cell and the standard 6 AH cell was insufficient in terms of cell voltage. Cell pressure characteristics were significantly different, the new prototype being superior. At higher charge rates, C/3.5 and C/3, the attributes of the thin plate design manifest themselves.

Although the differential existing between electrical characteristics are not great at low level charge rates, the trend exists in the favor of the thin plate cell, and a logical extension of the program is a thinner plate cell.

The rubber seal turned out to be quite unreliable, but a redesign of the seal, and possibly the cell to accommodate the seal design, could lead to a satisfactory solution. Required are a longer leak path, a means of preventing loss of bonding agent during molding, and thermal isolation between rubber and areas to be welded.

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INTRODUCTION

The objective of this contract was to develop, fabricate, and deliver to Goddard Space Flight Center, three hundred (300) prototype nickel-cadmium cells that conformed to "Specification For Prototype Nickel-Cadmium Cells for a Future Meteorological Spacecraft". These cells were to incorporate the latest advances in the state-of-the-art with respect to electrical and mechanical characteristics.

The contract was amended after inauguration of the program to include a study of a rubber seal for space applications. Fifty of the 300 cells were to be delivered with this seal.

The work was performed in three sections; design and development, production, characterization, and development of the rubber seal.

DESIGN

Size, Weight, and Shape

The cell design defines a prismatic cell, the dimensions of which are shown in Figure 1. The average weight for the cell is 268 grams. The range for the production group was from 263 to 277 grams, or 270 $\pm$ 7 grams. This is within $\pm$ 3%.

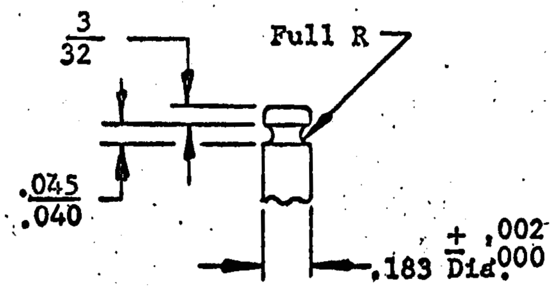
Components

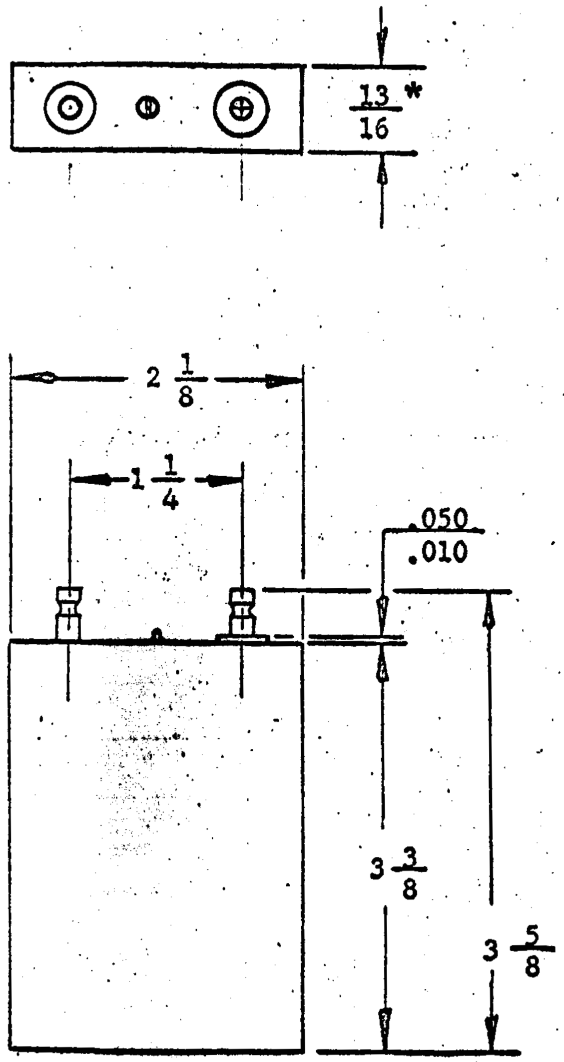
Both cell types, ceramic-to-metal and rubber seal, are made of the same parts with the exception of the seal.

The negative electrode is a sintered nickel plate on a nickel plate, cold rolled steel substrate, impregnated with cadmium hydroxide, with a total thickness of .025 inches. The positive electrode is plate similar to the negative but impregnated with nickel hydroxide to a total thickness of .027 inch. A total of 11 positive plates, 12 negative plates, and 1 Adhydrode comprise the electrode assembly.

A non-woven nylon separator .010 inch thick was used.

The electrode assembly is connected to the seal through a comb. The tabs of each electrode are inserted into the comb, crimped over and heli-arc welded. The comb is then arc welded to the cover assembly. The cover assembly consists of a cover, two isolated terminals, and an Adhydrode terminal.





SPECIFICATION

ELECTRICAL

Nominal Capacity	V06-HSB V06-HSAD V06-HSTPAD	6 Amp. Hrs.
Nominal Voltage		1.25 Volts
Operating Temp. Range		40°F to 100°F
Continuous Overcharge Capability		C/10 Amp. at 77°F
Overcharge Voltage At C/10 Rate & 77°F		1.41 to 1.43 volts
Discharge Voltage At C/2 Rate & 77°F		1.2 volts
End of Charge Voltage At C/5 Rate & 77°F		1.46 to 1.48 volts

FIG. 1 OUTLINE CELL VO6-HS TPAD SERIES

DEVELOPMENT

Initial Prototypes

The first group of cells were fabricated using 25 plates and a very thin separator (Pellon type 2505K). Testing indicated that 25 plates were not required to realize capacity and the separator system was less than adequate in terms of continuity.

Pre-Production Prototypes

The second group of prototypes used 23 plates and standard separator (Pellon type 2505 ML). Ten positive and eleven negative plates were cut in accordance with specifications (see Fig. 2 and Fig. 3). The edges were coated with a film of plastic and tabs inserted into combs. Tabs were crimped and then welded. The combs were then welded to a twin ceramic cover assembly, and the separator system was added, as well as the Adhydrode. A load of 6 tons was placed on the electrode assembly, and the assembly was checked for a shorting condition. A sheet of .005 nylon was used to wrap the completed electrode assembly prior to installation into the case. After installation, the cover was heli-arc welded to the case and the assembly was tested for leaks with a helium mass spectrometer. 15 cc's of 34% KOH was added and electrical testing begun.

Initial results gave vent to cautious optimism as capacity, pressure on charge and end-of-charge voltages were good, 6.5 to 7.2 AH, -17 in. hg -- + 7 psig, and 1.44 to 1.445 V, respectively, after 5 days at 1 ampere (C/6).

Based on this work, the mechanical design was frozen and electrical characteristics further investigated.

Optimizing Quantity of Electrolyte

The prototype cells were then tested as described in the following paragraphs to determine the proper amount of electrolyte. A theoretical value was determined and testing started at 15 cc's.

The cells were immersed in an oil bath and cell temperature monitored and kept at a constant temperature. Sensors were located on the center of the major face and in the center of a minor face. A temperature differential existed across the cell and was approximately 3°F. The temperature of the cells was taken as the temperature of the sensor on the major face, and was 79°F. The other sensor indicated 76°F.

Cells were charged at C/6 (1 amp) and permitted to stabilize.

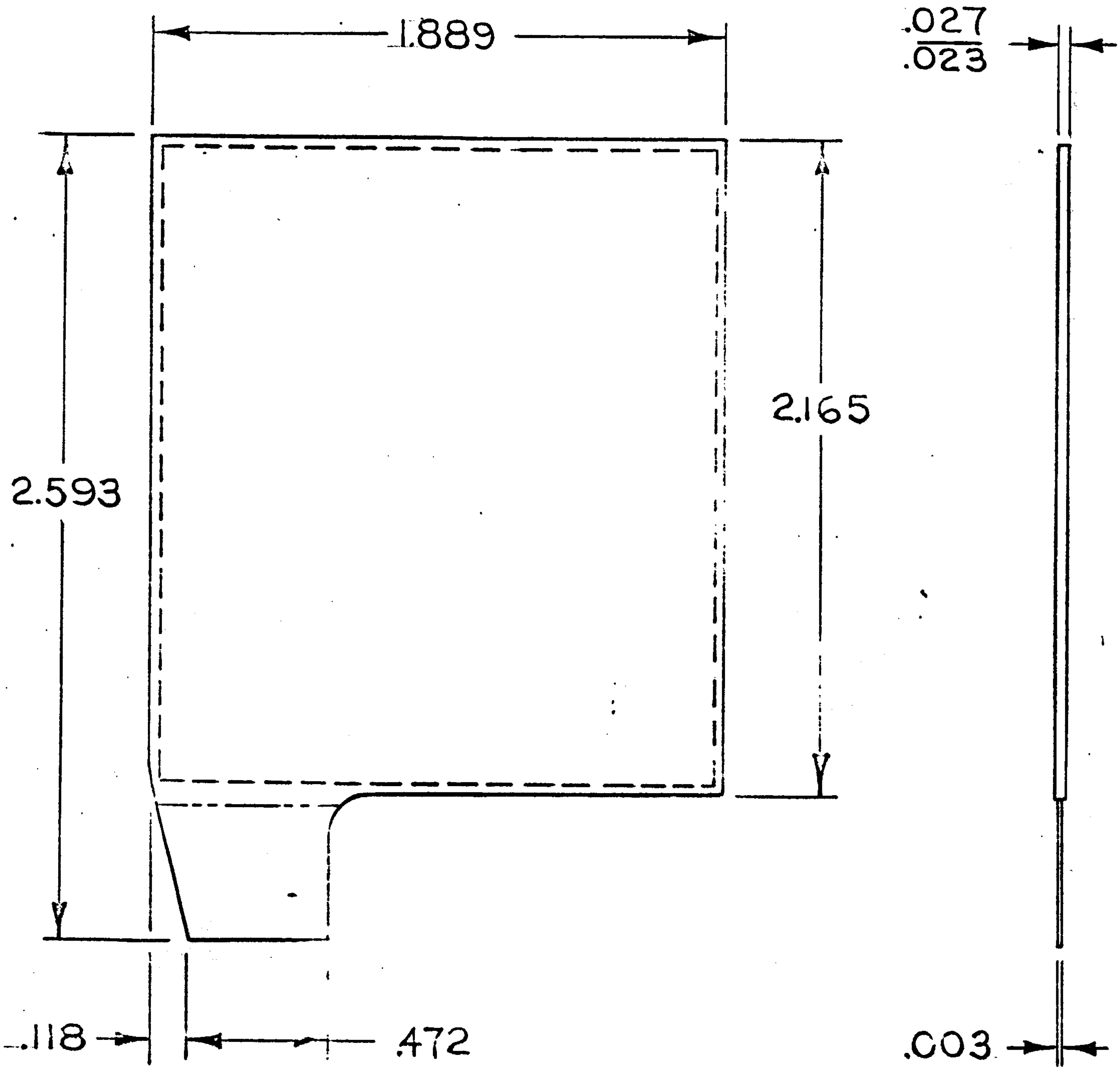


FIG. 2 PLATE POSITIVE VO-6HS TPAD

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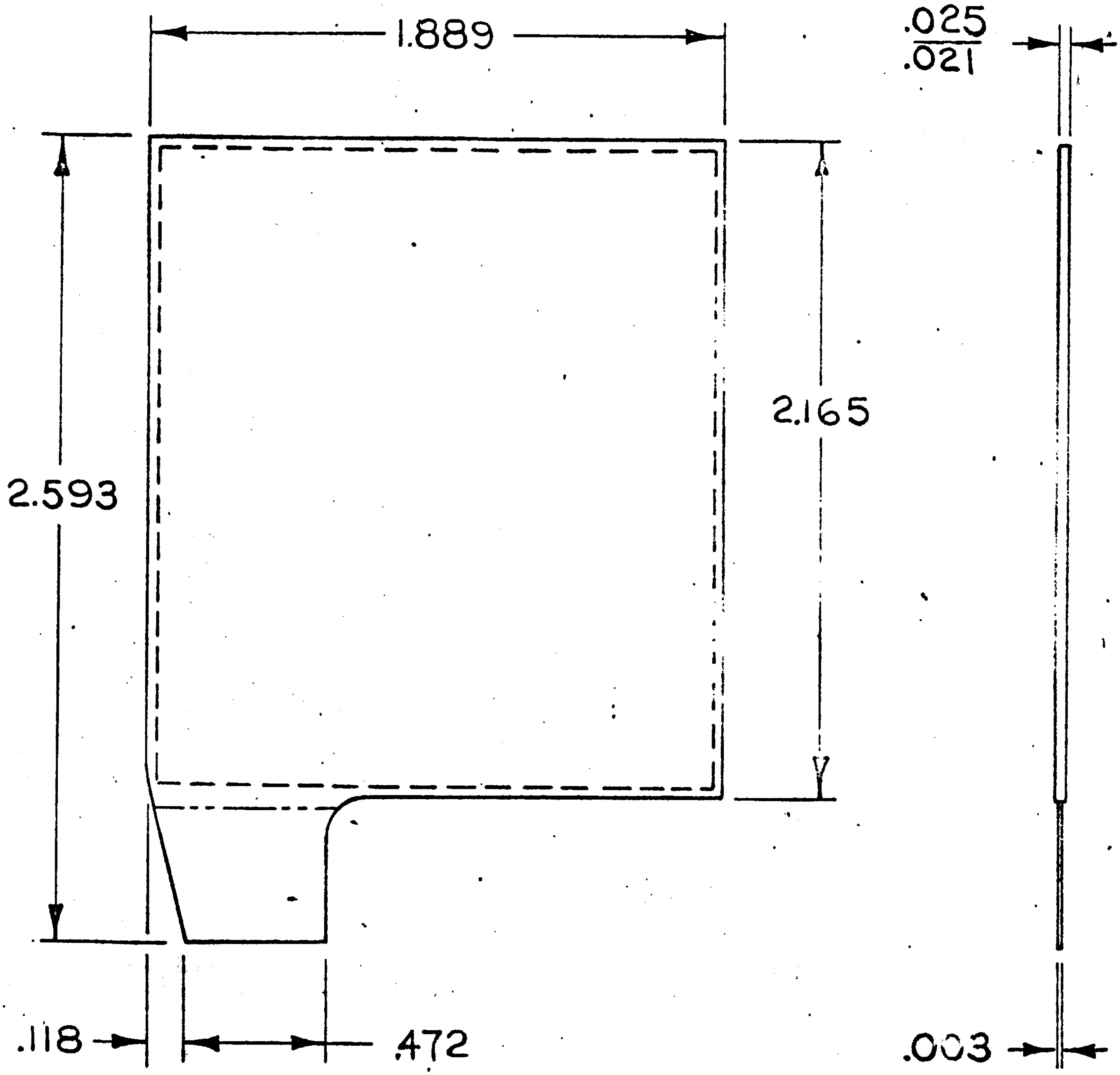

FIG. 3 PLATE NEGATIVE VO-6HS TPAD

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This took about 20 hours. Overcharge was continued for 24 hours minimum, and pressure, cell voltage and Adhydrode current monitored. The cells were then discharged at C/2 (3 amperes) to 1.0 volt. The same procedure was used as electrolyte was increased in ½ cc steps from 15 cc to 17 cc. A plot of range of capacity, pressure, and cell voltage is shown in Figure 4. The average cell voltage is also given in Table I. As may be seen, cell voltage does not vary greatly with quantity of electrolyte.

TABLE I - AVERAGE OVERCHARGE CELL VOLTAGE

QUANTITY OF ELECTROLYTE cc's	AVERAGE CELL VOLTAGE VOC *
15	1.45
15.5	1.451
16	1.44
17	1.45

* Adhydrode resistor connected.

Based on Figure 4 and Table I, 16 cc is the optimum quantity of electrolyte. At C/6, a cell voltage of 1.44, pressure 25 psig, and capacity of 7 AH may be expected.

Adhydrode Characteristics

After setting the quantity of electrolyte, the characteristics of the Adhydrode were investigated as a function of temperature. The cells were placed in a water cooled oil bath. The oil was rapidly circulated around each cell by means of baffles. A thermostat on one cell was used as the control and actuated the cooling water valve. The Adhydrode characteristics are shown in Figures 5 and 6. As may be seen, the characteristics at 25°C and 40°C are quite similar to each other and the knee of the curve well defined. Cell control through Adhydrode action is, therefore, feasible.

Production - Cells

After establishing mechanical design, electrical characteristics, manufacturing procedures, and production tooling, an initial production order of 100 cells was initiated. Five cells were taken from this group and tested. Cell voltage and pressure were monitored and values after stabilization are shown in Table 2.

These five cells were also subjected to a continuous charge at C/8 and 77°F, and the voltage was monitored during this charge. These data are listed in Table III. As may be seen, the cell voltage peaks after 10-11 hours, and then tends to decrease at a very slow rate.

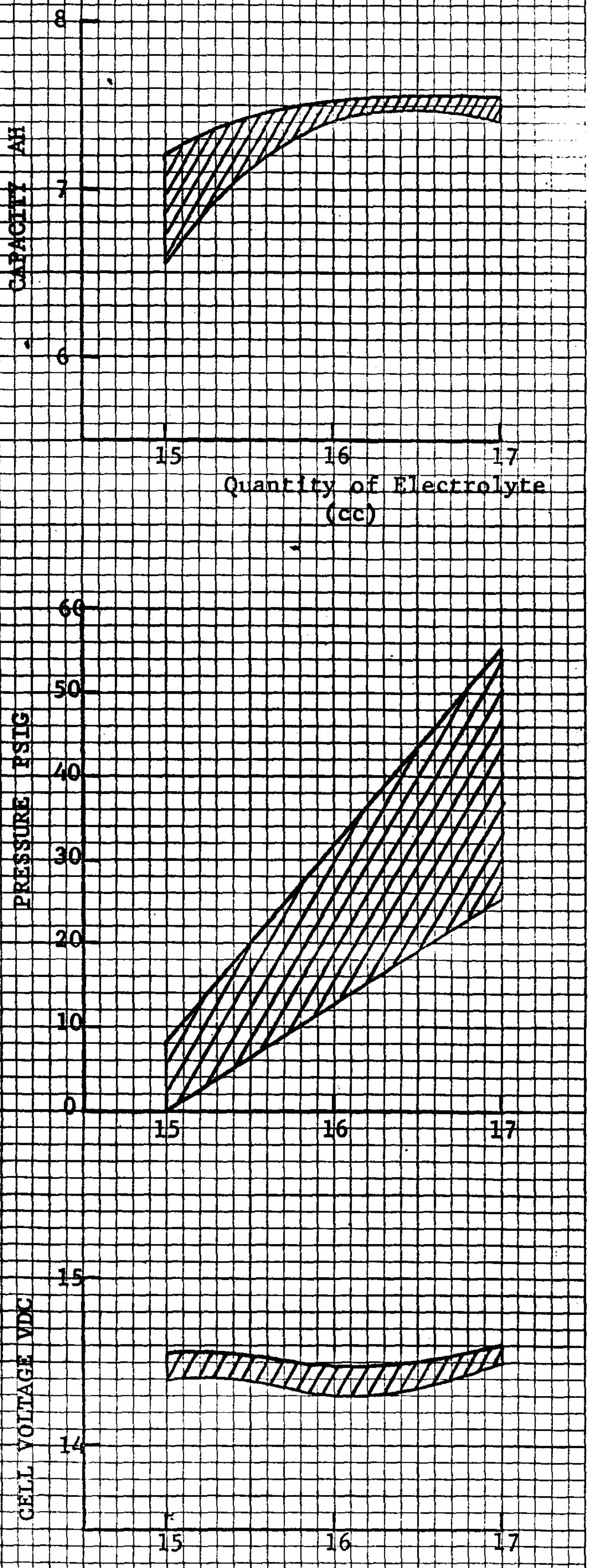

FIGURE 4. VO-6 HS TPAD
EQUILIBRIUM CONDITIONS
WHEN CHARGED AT C/6 (1 A)
CELL TEMP. HELD AT 79°F

CAPACITY AFTER OVERCHARGE
CAP. TO 1.0 V AT 3A RATE

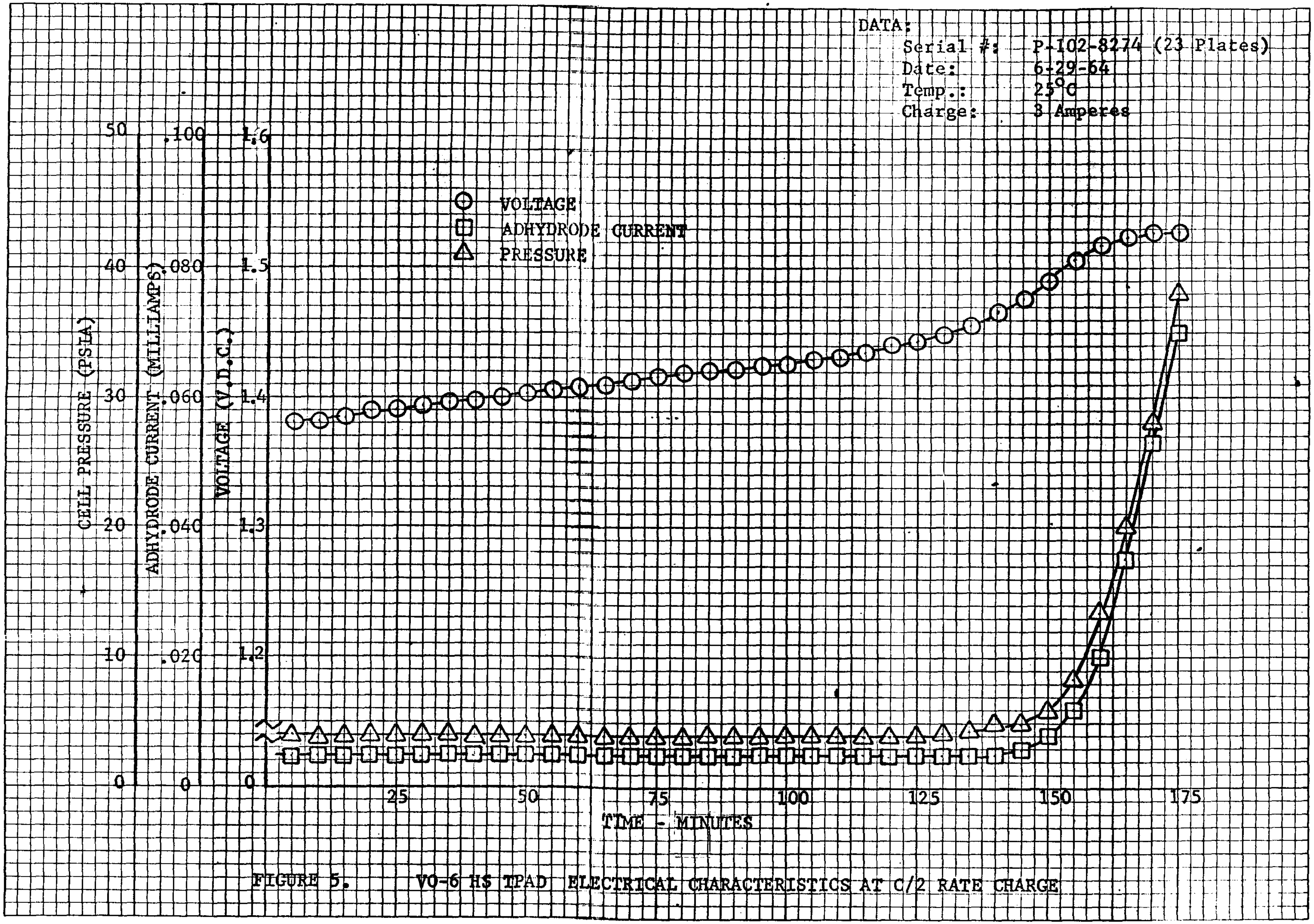

FIGURE 5. VO-6 HS TPAD ELECTRICAL CHARACTERISTICS AT C/2 RATE CHARGE

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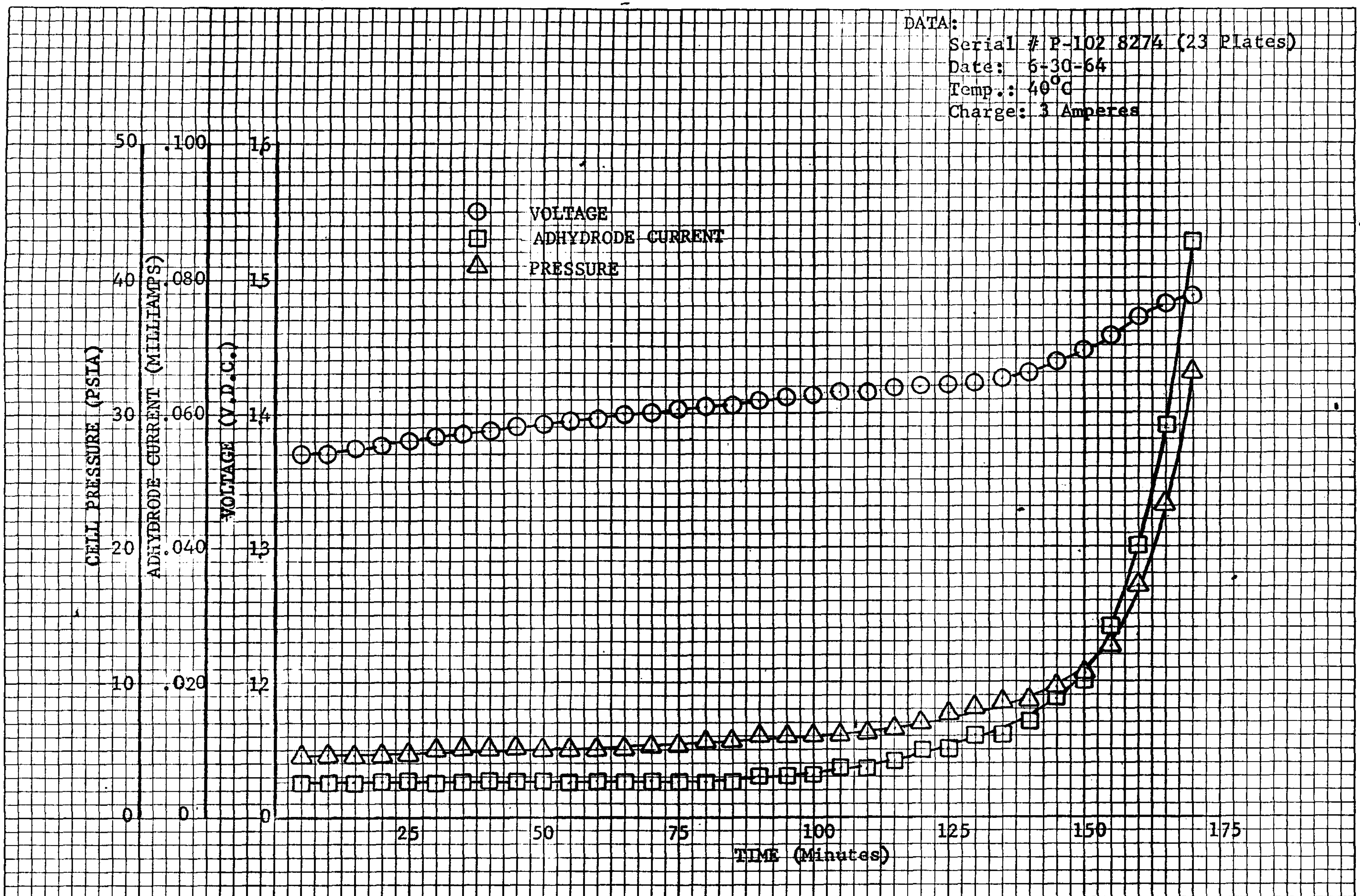

FIGURE 6. VO-6 HS TPAD ELECTRICAL CHARACTERISTICS AT C/2 RATE CHARGE

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TABLE II. PRODUCTION CELLS-OVERCHARGE CHARACTERISTICS

	RATE	TEMPERATURE	VOLTAGE	PRESSURE
50°C	C/10 (.600A)	101-102°F	1.36	-14 to +3
	C/8 (.750A)	103-105°F	1.36	-16 to +4
	C/6 (1.0A)	105-107°F	1.37	-13 to +6
	C/4 (1.50A)	105-106°F	1.375	-7 to +13
	C/3 (2.0A)	105-107°F	1.38	-2 to +17
	C/10 (.60A)	74-79°F	1.43	0 to 19
	C/8 (.750A)	78-80°F	1.42	0 to 21
	C/6 (1.0A)	75-78°F	1.43	3 to 26

TABLE III. ON CHARGE VOLTAGE CHARACTERISTICS
VO-6HS TP AD

TIME ON CHARGE CHARGE RATE .750 A	CELL NUMBERS 1	2	3	4*	5*
15 Min.	1.32+	1.31	1.315	1.31-	1.31+
1 Hr. 15 Min.	1.36	1.35+	1.36	1.36-	1.36
2 Hr. 15 Min.	1.38-	1.37	1.38-	1.375	1.38
3 Hr. 15 Min.	1.39-	1.38	1.39-	1.39-	1.39-
4 Hr. 15 Min.	1.395	1.39	1.395	1.395	1.395
5 Hr. 15 Min.	1.40	1.395	1.40	1.40	1.40
6 Hr. 15 Min.	1.405	1.40+	1.405	1.405	1.405
7 Hr. 15 Min.	1.41+	1.41-	1.41+	1.41+	1.41+
8 Hr. 15 Min.	1.42-	1.41+	1.42-	1.415	1.42-
8 Hr. 45 Min.	1.42+	1.42-	1.42+	1.42	1.42+
9 Hr. 15 Min.	1.43	1.42+	1.43	1.425	1.43-
9 Hr. 45 Min.	1.44-	1.43	1.435	1.43-	1.43+
10 Hr. 15 Min.	1.45-	1.44-	1.44	1.43	1.435
10 Hr. 45 Min.	1.45-	1.44+	1.44-	1.43+	1.435
11 Hr. 15 Min.	1.445	1.435	1.435	1.425	1.43
12 Hr. 15 Min.	1.445	1.435	1.44	1.43	1.435
13 Hr. 15 Min.	1.44	1.43+	1.43+	1.425-	1.43-
14 Hr. 15 Min.	1.44+	1.43+	1.43+	1.425	1.43
15 Hr. 15 Min.	1.44+	1.435	1.435	1.425	1.43
16 Hr. 15 Min.	1.44-	1.43-	1.43-	1.42	1.435

* Cells #4 and #5 have a load resistor between Adhydrode terminal and negative terminal--other cells do not.

CHARACTERIZATION

An in-house test program was introduced at Gulton Industries to determine basic minimum cell characteristics for the production cells. Table IV summarizes the characteristics of 199 cells. These data are taken from in-air bench tests. A temperature sensing device was utilized on every fifth cell to determine if cell temperature was at 77°F ± 2°F.

The bench data, as taken at Gulton Industries, did not concur with test data of the same cells when tested at the Goddard Space Flight Center. This was particular in regard to capacity and cell voltage on overcharge. An interim program was instituted to review cell characteristics under more tightly controlled conditions. An interim report was issued, and a portion is attached as Appendix I. Recapitulating the results of this program, it was found that cell voltage and pressure increased as the quantity of electrolyte was increased from 16 cc to 19.5 cc. The test program included a study of the rate at which the cell could be overcharged. A standard VO-6 HS was used as a control. No marked difference in voltage characteristics between the control cell and the thin plate cell occurred until charge rates became high (C/3). At this point, the advantages of thin plate construction began to show up. The thin plate cell was consistently lower in pressure than the control or standard cell. It is felt that this differential in pressure partly accounts for the similar voltage levels as not enough oxygen is present to depolarize the negatives.

TABLE IV. SUMMARY PRODUCTION TEST CHARACTERISTICS

GROUP NO.	NO. OF CELLS	AVERAGE CAPACITY A.H.	AVERAGE OVERCHARGE CHARACTERISTICS		
			VOLTAGE VDC	PRESSURE PSIG	ADHYDRODE CURRENT MA
1	16	6.30	1.43	8	110
2	4	6.70	1.40	5	115
3	29	6.75	1.40	3	100
4	12	6.80	1.42	3	95
5	24	6.60	1.40	5	115
6	30	6.0	1.39	2	95
7	40	7.0	1.42	8	100
8	16	7.0	1.38	2	65
9	13	7.1	1.40	-2	105
10	15	6.85	1.42	9	110

CAPACITY DETERMINATION

In addition to the work on overcharge characteristics, we investigated means of determining cell capacity within a 24 hour period. The cycle consists of:

1. A cell which has been discharged to 1.0 volt is shorted with a 1 ohm resistor for 16 hours.

2. Remove 1 ohm short and dead short for 1 hour.

3. Remove dead short and charge at 3.0 amperes for 2 hours, 15 minutes.

4. Reduce charge to 0.6 ampere and continue for 1 hour, 45 min.

5. Place on open circuit for 5 minutes.

6. Discharge at 3.0 amperes to 1.0 volts. Record capacity.

The capacity for three cycles per described method is given in Table V. Cycle #1 was slightly modified (charge at 3.0 amperes for 2 hours, 30 minutes) and this accounts for high end-of-charge voltage, as shown in Table VI.

TABLE V. CELL CAPACITY USING 24 HOUR ROUTINE

CELL NO.	CAPACITY		
	CYCLE NO. 1	CYCLE NO. 2	CYCLE NO. 3
234	6.95	6.55	6.85
236	7.05	6.55	6.90
246	6.90	6.50	6.75
276	6.65	6.45	6.60
279	6.95	6.55	6.80

It would appear that the method yields a higher capacity than if the 600 ma charge method is used (where our capacity is 6.55). Cycles 1 and 3 are quite uniform.

TABLE VI. CELL VOLTAGE USING 24 HOUR ROUTINE

CELL NO.	END OF 3.0 AMPERE CHARGE VOLTAGE		
	CYCLE NO. 1	CYCLE NO. 2	CYCLE NO. 3
234	1.48	1.47	1.46
236	1.47	1.45	1.45
246	1.49	1.45	1.46
276	1.50	1.46	1.48
279	1.50	1.45	1.47

We conclude that (1) it is possible to determine capacity within a 24 hour period, (2) the maximum voltage during the charge period will be 1.48 and will occur at the end of the 3.0 ampere charge, and (3) the capacity will be approximately .30 AH higher than if the slow charge (600 ma until stabilization) is used.

RUBBER SEAL PROGRAM

Introduction

The objective of this program was the development of a rubber seal for use on VO-6 TPAD cells.

Seal Design

The configuration of the rubber seal assembly is shown in Fig. 3B, Appendix II. Each seal consists of four parts; the spool which is brazed to the cover, the neoprene gasket which is molded in place and bonded in a single operation, the bushing, and the terminal which is welded to the bushing to complete the seal.

Two molding and bonding methods were used in the construction of these seals for the testing program. They were:

1. Transfer molded, with all parts in contact with the neoprene fabricated of "A" nickel. Bonding was dependent on the affinity of the vendors neoprene for nickel.

2. Compression molded, with the metal portions of the seal fabricated of cold rolled steel. Bonding was accomplished through the use of a bonding agent applied to the metal parts prior to the molding operation.

Seal Testing

Force vs. Deflection.- Both types of seals were subjected to compression testing to determine the strengths of the rubber to metal bonds.

The results of this testing showed the compression molded seals incorporating a bonding agent to be superior to those manufactured by the first method described above. The compression molded seals had an average breaking strength exceeding 200 lbs., as opposed to 30 lbs. for the transfer molded seals.

Because the transfer molded seals failed to meet the minimum specification load of 50 lbs., it was decided to eliminate them from the program.

In the interest of having more than one source, a new vendor was contacted, and seals were purchased which were fabricated in a manner similar to the compression molded seals. These seals, when tested, also exceeded 200 lbs. breaking strength.

Life Testing. - Three test fixtures were supplied to Gulton by NASA, Goddard Space Flight Center, for life testing the seals. A description of the fixtures and life test program can be found in Appendix II.

Twenty-four of each of the available seal types were assembled in the test fixtures and the testing was initiated. After three days of testing, the test fixtures began to leak KOH. These leaks occurred at the silver brazed joints of the bellows assemblies, and efforts to seal the fixtures proved unsuccessful. Concurrently with the life testing, cells were fabricated using both types of seals. From the results of the cell construction, described in the following section, it was decided to suspend the life testing.

Construction Of Cells

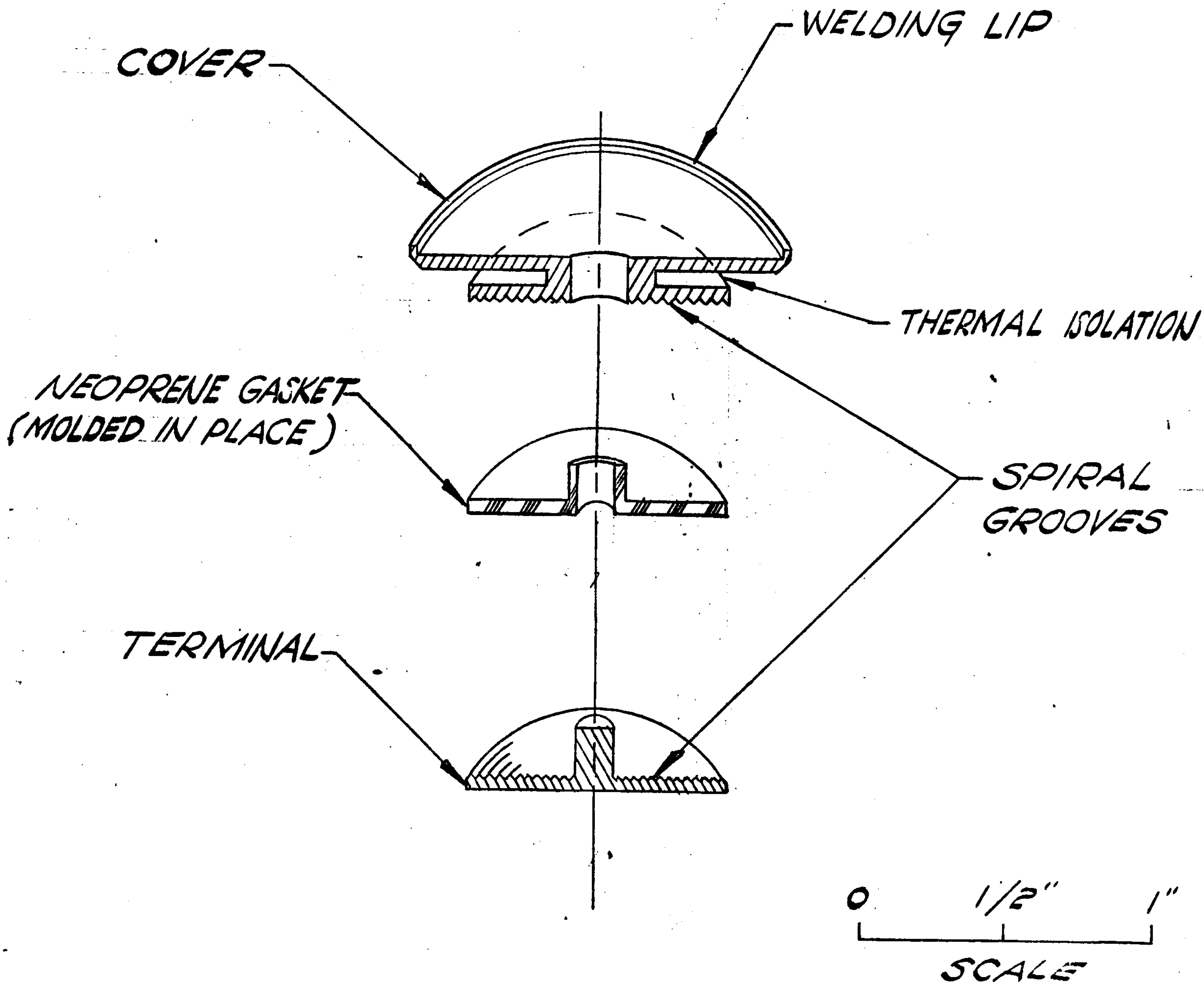
Thirty VO-6 TPAD cells were constructed using fifteen of each of the two types of seals. Following fabrication, the cells were helium leak checked, activated and subjected to electrical processing. During the electrical processing period, approximately five weeks, fifteen of the cells developed leaks at the rubber seals. Due to these results, it was decided to suspend the life testing and terminate the program.

Conclusions

Analysis of the cell failures, the seal design, and the fabrication and assembly methods has led to the following conclusions.

1. The rubber seal should be redesigned to provide the following:
   a. Longer leak path.
   b. Some means to prevent the wiping away of the bonding agent by the rubber during the molding process.
   c. Adequate isolation of the rubber seal from areas to be welded.
2. Improved heat sinking methods must be developed to protect the rubber seal from the heat of welding associated with cell assembly.

These conclusions have been borne out where a similar type of rubber seal was used for "D" and "F" size spiral cells. Two hundred of these cells were constructed under Contract NAS5-7219, during the period from March 1965 through June 1965. To date, none of these cells have shown evidence of leakage at the rubber sealed terminal. The configuration of these seals is shown in Figure 7. As can be seen from the drawing, the leak path is greater than on the seals used in the VO-6TPAD cells. Another significant difference between the two types of seals is the grooving of the adjacent metal parts. The effect of these grooves is twofold; (a) increased leak path, and (b) retention of the bonding agent during the molding operation.



RUBBER SEAL-"D" & "F" CELL

FIGURE 7

A compression molding process is used in the fabrication of these seals. In this process, a bonding agent is applied to the parts, which are then assembled into a suitable mold with a preform of the uncured rubber placed between them. Heat and pressure are applied, molding the rubber to the desired areas in the part and extruding the excess through vents in the mold. This movement of the rubber across the surfaces of the parts can, unless steps are taken in the design of the parts, wipe away the bonding agent, resulting in poor adhesion.

APPENDIX I

INTERIM STUDY OF CELLS

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APPENDIX I

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APPENDIX I. - INTERIM STUDY OF CELLS

Object

The object of this program was to determine the electrical characteristics of the VO-6 HS TPAD and VO-6 HS cells. Of prime concern are voltage and pressure characteristics as a function of overcharge current, and voltage and pressure characteristics as a function of quantity of electrolyte. The former test was run in an oil bath and the latter in an air bath. The tests are described in the following paragraphs.

TEST 1. - RECHECK OF QUANTITY OF ELECTROLYTE

I. CELLS TO BE USED

A. 2 Standard VO-6HS cells from current production.

B. 2 of the original 23 thin plate prototypes. These were taken from the first production lot. These have 16 cc KOH.

C. 2 of the original 23 thin plate prototypes to which 3.5 cc's have been added; therefore a total of 19.5 cc.

D. 2 VO-6 HS TPAD cells taken from the present production lot to which 1 cc has been added for a total of 17 cc.

E. 2 VO-6 HS TPAD cells taken from the present production lot to which 2 cc has been added for a total of 18 cc.

II. GENERAL INSTRUCTIONS

A. One cell of each Adhydrode group is to have a ½ ohm resistor connected from the negative terminal to the Adhydrode.

B. A thermocouple is to be attached to each positive terminal.

C. Cells are to be in metal restraining plates. A thin film of silicone grease is to be used between the cell wall and jacket.

D. Monitor cell voltage, pressure, temperature and Adhydrode current.

E. Use a fan to cool the cells.

III. TEST PROCEDURE

A. List of cell serial numbers and conditions.

S/N	TYPE	QUANTITY KOH (cc)	ADHYDRODE CONNECTED	REMARKS
5833	VO-6HS		---	From present production
5834	VO-6HS		---	From present production
105	VO-6HS TPAD	16	Yes	From first production lot
106	VO-6HS TPAD	16	No	
249	VO-6HS TPAD	17	Yes	
250	VO-6HS TPAD	17	No	From present production
251	VO-6HS TPAD	18	Yes	
253	VO-6HS TPAD	18	No	
108	VO-6HS TPAD	19.5	No	
111	VO-6HS TPAD	19.5	Yes	From first production lot

These cells were placed on charge at 1300pm on March 22, 1965, at 750 ma. Data was recorded at 0900 on March 23, 1965, 1700 on March 23, and 1000 on March 24, 1965, as shown in Table I.

TABLE I.

OVERCHARGE AT .750 AMPERE IN AN AIR BATH

CELL NO.	VOLTAGE 0900 3-23	VOLTAGE 1700 3-23	VOLTAGE 1000 3-24	PRESSURE 0900 3-23	PRESSURE 1700 3-23	PRESSURE 1000 3-24	TEMPERATURE 0900 3-23	TEMPERATURE 1700 3-23	TEMPERATURE 1000 3-24	QUANTITY KOH	ADHYDRODE CONNECTED
5833	1.44	1.43	1.44	16	17	18	75		76	STD	
5834	1.44	1.43	1.44	18	21	22	77.5		77	STD	
105	1.41	1.40	1.42	-5	-5	-5	80		80	16	X
106	1.43	1.42	1.44	8	9	8			76	16	
249	1.46	1.44	1.45	19	20	18	77		77	17	X
250	1.45	1.44	1.45	26	30	30	78		77.5	17	
251	1.46	1.44	1.46	32	36	35	74		76	18	X
253	1.46	1.44	1.46	36	44	40	75		76	18	
108	1.45	1.43	1.46	7	8	5	75		77	19.5	
111	1.50	1.46	1.51	21	26	38	78		78	19.5	X

In general certain conclusions may be drawn from this test.

1. Cell voltage tends to increase with quantity of electrolyte. The thin plate six is comparable to the VO-6HS in terms of voltage when 16 cc KOH is used. It cannot be clearly ascertained whether or not Adhydrode connection makes a difference. Cell voltage is temperature sensitive.

2. Cell pressure increases with addition of electrolyte. A VO-6HS TPAD with 16 cc of KOH operates at a lower pressure than a standard VO-6. In general, a cell runs at a lower pressure when the Adhydrode is connected. No correlation exists between pressure and temperature.

TEST 2.

I. CELLS TO BE USED

A. 3 Standard VO-6HS cells from current production.

B. 3 VO-6HS TPAD cells from current production. These have the standard quantity of KOH (16 cc).

II. GENERAL INSTRUCTIONS

A. Do not connect Adhydrode to negative terminal.

B. A thermocouple is to be attached to each positive terminal.

C. Cells are to be in metal restraining plates. A thin film of silicon grease is to be used between the cell wall and jacket.

D. Monitor cell voltage, pressure and temperature.

E. Cells are to be immersed in an oil bath. Monitor oil bath temperature. If a marked difference exists between oil bath and cell temperature, then try to hold cell temperature to 77°F.

F. Oil bath is to be controlled by constant cooling with water and intermittent heating with an immersion heater.

III. TEST PROCEDURE AND RESULTS

LIST OF SERIAL NOS. & CELL TYPE

S/N	CELL TYPE
255	VO-6HS TPAD
257	VO-6HS TPAD
258	VO-6HS TPAD
5830	VO-6HS
5831	VO-6HS
5832	VO-6HS

TEST

A. At 1700 on March 22, 1965, these cells were placed in an oil bath and placed on charge at 750 ma (C/8).

At 0940 on March 23, 1965, cell data was recorded and is shown in Table II.

TABLE II

S/N	VOLTAGE	PRESSURE
255	1.46	9
257	1.46	12
258	1.45	12
5830	1.44	21
5831	1.45	25
5832	1.44	17

At 0940 on March 23, 1965 the rate was changed to 1.5 amperes, (C/4). Table III summarizes the data taken from 0940 to 1640.

TABLE III.

OVERCHARGE AT C/4 IN OIL BATH

SERIAL NO.	1100			1330			1400			1455			1525			1640		
	V	P	T	V	P	T	V	P	T	V	P	T	V	P	T	V	P	T
255	1.43	1		1.45	10	71	1.45	10	71	1.45	20	76	1.48	21	75	1.48	22	76
257	1.45	7	77.5	1.46	14	71	1.46	14	71	1.48	24	77	1.49	25	77	1.48	27	77
258	1.45	4	79.5	1.45	12	74.5	1.45	12	74.5	1.48	23	85	1.48	24	83	1.48	25	82
5830	1.43	13	77	1.44	23	71	1.44	23	71	1.48	39	77	1.47	44	76	1.47	50	77
5831	1.45	17	78.5	1.46	30	71	1.46	30	71	1.48	47	76	1.49	51	76	1.48	63	76
5832	1.43	9		1.44	17	71.5	1.44	17	71	1.47	33	79.5	1.47	37	80	1.46	42	76

With reference to Table III and the data from which it was taken, the following comments may be made. The VO-6HS TPAD had stabilized as evidenced by constant pressure over 3-4 readings every 10 minutes for 30-40 minutes. During this same period, the VO-6HS cells rose from 3 to 7 psig. It would appear, however, that the rate of pressure change in the VO-6HS had declined somewhat and was approaching stabilization.

At 1700 on 3-23-65, the charge rate was reduced from 1.5 amperes (C/4) to 0.75 ampere (C/8).

B. At 0900 on 3-24-65, voltage, pressure, and temperature were again monitored and are shown in Table IV.

TABLE IV.

OVERCHARGE AT C/8 IN OIL BATH

SERIAL NO.	V VDC	P PSIG	T ^{o}F
255	1.46	11	71
257	1.46	14	71
258	1.46	12	72.5
5830	1.44	27	71
5831	1.45	42	71
5832	1.45	22	71

C. At 0920 on 3-24-65, the rate was increased to 1.71 amperes (C/3.5). Characteristics were monitored periodically and at 1435 on 3-24-65, Cell S/N 255, 257, and 5830 were taken and the gas content analyzed with a Barrell Gas Analyzer. Cell #257 was done incorrectly, in that the input line to the analyzer was not properly evacuated. Cell #255 yielded 12% H_2 and Cell #5830 yielded 20% by volume. After testing the cells were charged with O_2 to their pressure prior to the test. Cell #257, however, was charged to 58 psig (the average pressure of VO-6HS - excluding 5831.) Voltage dropped from 1.47 to 1.45. Table V summarizes this test.

TABLE V.

OVERCHARGE AT C/3.5 IN OIL BATH

S/N	20 MIN.			1½ HR.			2½ HR.			4HR.15MIN.			4HR.45MIN.			GAS ANALYSIS	6HR.45MIN.			7HR. 15MIN.			7 HR. 45 MIN.		
	V	P	T	V	P	T	V	P	T	V	P	T	V	P	T		V	P	T	V	P	T	V	P	T
255	1.52	18		1.46	25	79	1.47	28	78	1.47	28	78	1.46	29	80	12% H_2 **	1.46	39	78.5	1.45	38	79	1.46	37	78.5
257	1.52	21		1.47	32	81	1.48	33	79	1.48	34	79	1.47	35	80	*	1.47	41	80.5	1.46	41	81	1.47	39	79.5
258	1.52	20		1.46	30	84.5	1.46	30	78	1.48	34	77.5	1.47	35	80		1.48	34	79	1.47	35	80	1.49	39	79
5830	1.49	36		1.45	50	90	1.45	46	78	1.49	58	77	1.46	62	79	20% H_2 **	1.49	18	78.5	1.48	17	79	1.49	16	78
5831	1.51	51		1.47	70	79.5	1.48	78	75.5	1.48	88	77.5	1.48	91	78		1.49	94	81	1.48	95	81.5	1.48	95	80
5832	1.49	30		1.45	40	80	1.46	48	78.5	1.46	52	78	1.45	54	79		1.46	55	79	1.45	56	79.5	1.46	56	78

* Vent and Charge with O_2 to 58 psig. V = 1.45 after O_2 Charging.

** Refill to original pressure with O_2

Comments on Table V

It appears that the characteristics of 5830 have changed considerably due to the introduction of oxygen. This is particularly evidenced by the decline in pressure. This also appears to be the point where the thin plate cell becomes equal to or superior to the standard VO-6 with regard to voltage.

D. At 1700 on 3-24-65, the charge rate was reduced from 1.71 amperes to 0.75 ampere.

At 0845 on 3-25-65, overcharge data at 0.75 ampere was recorded. This is shown in Table VI below.

TABLE VI.

OVERCHARGE AT C/8 IN OIL BATH

SERIAL NO.	V VDC	P PSIG	T °F
255	1.46	11	76
257	1.47	13	76.5
258	1.46	11	76.5
5830	1.47	9	76
5831	1.46	38	78
5832	1.43	20	76

E. At 0945 on 3-24-65, the charge rate was increased from 0.75 ampere (C/8) to 1.71 amperes. At 1330, each cell was tested for H_2 using the "torch test". Pressure was monitored before the torch test, and the cell repressurized to this initial pressure after the torch test. Table VII summarizes this data.

TABLE VII

OVERCHARGE AT C/3.5 IN OIL BATH

SERIAL NO.	1 HOUR			2 HOURS			3 HR. 45 MIN.			TORCH TEST
	V	P PSIG	T ^oF	V	P PSIG	T ^oF	V	P PSIG	T ^oF	
255	1.47	36	78	1.45	36	78.5	1.47	38	79.5	O_2
257	1.49	35	81	1.49	37	81	1.48	37	81	O_2
258	1.48	30	79	1.49	31	79.5	1.48	33	79	O_2
5830	1.50	15	79	1.50	15	78.5	1.50	15	79	O_2
5831	1.50	70	79	1.50	79	79.5	1.49	90	79	O_2
5832	1.47	42	78.5	1.47	49	78.5	1.45	60	79.5	O_2

At 1440 on 3-24-65, the rate was reduced to 750 ma (C/8). At 1700 it was increased to 1.0 ampere (C/6).

F. At 0900 on 3-29-65, after 64 hours at 1 ampere, data was recorded and is shown in Table VIII.

TABLE VIII

OVERCHARGE AT C/6 IN OIL BATH

SERIAL NO.	V VDC	P PSIG	T ^oF
255	1.44	17	77
257	1.45	17	77
258	1.44	15	77
5830	1.43	18	77
5831	1.44	38	77
5832	1.43	32	77

It should be noted that the cells are at a lower voltage after 64 hours at C/6 than after 16 hours at C/8.

G. At 0915 on 3-29-65, the rate was increased from 1 ampere (C/6) to 2.0 amperes (C/3). Table IX summarizes the data taken over a 5 hour period.

TABLE IX

OVERCHARGE AT C/3 IN OIL BATH

SERIAL NO.	1 HOUR			1 HR. 15 MIN.			1 HR.30 MIN.			2 HR.30 MIN.			5 HOURS			TORCH
	V	P PSIG	T ^{o}F	V	P PSIG	T ^{o}F	V	P PSIG	T ^{o}F	V	P PSIG	T ^{o}F	V	P PSIG	T ^{o}F	
255	1.46	34		1.48	34	79	1.48	34	76	1.49	35	76.5	1.50	36	73	O_2
257	1.47	33		1.49	34		1.49	34		1.49	35	78	1.50	37	76.5	O_2
258	1.47	29	83	1.49	29	80	1.49	29	78	1.49	30	78	1.50	32	75.5	O_2
5830	1.47	39	81	1.50	39	80	1.52	39	78	1.52	40	78	1.53	46	75	H_2
5831	1.48	67	81	1.51	70	80	1.52	71	78	1.52	79		1.53	97		O_2
5832	1.45	56	81	1.47	58	79	1.47	58	77	1.52	64	76.5	1.49	72	73	O_2
Bath Temp.	25°C			24°C			23°C									

After the torch test, the cells were recharged to their original or pre-vent pressure and S/N 5830 was removed from the circuit. The rate of Charge was reduced from 2A (C/3) to 0.75A (C/8).

H. At 1100 on 3/30/65, the charge rate was changed from 0.75A (C/8) to 1.2A (C/5). At 0900, 3/31/65 (22 hours later) data was recorded and is shown in Table X.

TABLE X

OVERCHARGE AT C/5 IN OIL BATH

SERIAL NO.	V VDC	P PSIG	T ^{o}F
255	1.44	18	77.5
257	1.46	18	78.5
258	1.45	20	79.5
5831	1.47	49	77.5
5832	1.43	34	77.5

I. At 0915 on 3-31-65, the rate was reduced from 1.2 amperes to .750 amperes (C/8). At 1545, data was recorded and is summarized in Table XI.

TABLE XI

OVERCHARGE AT C/8 IN OIL BATH

SERIAL NO.	V VDC	P PSIG	T ^{o}F
255	1.41	8	77
257	1.43	9	77
258	1.42	11	78
5831	1.42	33	78
5832	1.40	19	77

Bath at 24.5^{o}C

IV. SUMMARY TEST II

Tables I and II show averages of cell conditions. If we attempt to show a range, the results become meaningless. This is probable due to the small sample.

Table XI is of special interest, as noted by low cell voltages and uniform temperature.

APPENDIX II

TEST PROGRAM

RUBBER SEALED HEADER ASSEMBLIES

FOR

VO-6 ADHYDRODE CELLS

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APPENDIX II

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LIST OF FIGURES

I. INTRODUCTION

The purpose of this test program is to subject a comprehensive sampling of rubber sealed VO-6 Header Assemblies to the physical and chemical stresses encountered during the construction and life of a VO-6 cell.

Two types of header assemblies will be tested. The only differences between the two types is the method of bonding the rubber to the metal parts, and the material of which the metal parts are fabricated. Twenty-seven specimens of each type are to be tested.

Following the evaluation of the test data, 50 VO-6 Adhydrode cells will be assembled using the header type proven to have the greater reliability.

II. TEST PLAN

The basic test plan is as shown in Figure 1. This chart outlines the major steps to be taken, starting with the selected specimens of each type, the various tests to be performed and ending with the test report. The test program will consist of two phases, A and B.

Phase A involves 3 samples of each type assembly. The objective of this phase is to determine the basic physical properties of the header assemblies, and to determine what degradation of the seal to expect during the construction processes. These processes consist primarily of welding the electrode assembly to the terminals, and welding the header assembly to the cell container.

Phase B is an accelerated life test. The testing will be accomplished using three test fixtures supplied by NASA-Goddard. These fixtures are designed to duplicate the environment found in a nickel-cadmium cell, including exposure to potassium hydroxide, oxygen and a cycling pressure change. The fixtures will each be mounted in an oven. The ovens will operate at three different temperatures, 40°C, 65°C, and 90°C. The pressure cycle consists of alternately applying pressures of 50 psig and atmospheric at 3 minute intervals. The cycling will run continuously for the 12 week duration of this test, resulting in approximately 20,000 cycles.

III. TEST PROCEDURE

The following is a detailed description of the tests to be performed in accordance with the steps outlined in the Test Plan, Figure 1.

A. PHASE A - TESTING

1. Selection of Test Specimens

One hundred of each type header assembly are to be fabricated. Twenty-seven of each type are to be randomly selected from these groups. These fifty-four headers will constitute the test specimens. From these groups of twenty-seven, three of each type will be randomly selected for Phase A testing.

2. Physical Testing

2.A.1. "Veeco" Mass Spectrometer Leak Chekc.

2.A.2. Force versus deflection
For test arrangement, see Figure 2

2.A.2.1. First sample of each type to be tested to destruction.
Purpose: To establish test levels for remaining two specimens.

2.A.2.2. Remaining specimens to be tested to 50% of yield level established above.

2.A.3 Repeat Step 2.A.1 (Leak Test)
Record all data

3. Welding Investigation

3.A.1. Weld terminals in place in accordance with Figure 3A. Record temperatures at thermocouples during welding operation.

3.A.2. Weld cover into container in accordance with Figure 3B. Record temperatures at thermocouples during welding operation.

4. Physical Testing

Repeat Step 2A, except 2.A.2.1
Record data.

5. Section and Evaluate

Cross-section the header assemblies through the terminals and visually examine the bonded areas for signs of degradation due to heat, stress, etc. Specimens shall be identified and marked. All discrepancies are to be documented and photographed where necessary to clearly describe the defect.

B. PHASE B - TESTING

Step 2B

Weld remaining 24 of each type assembly previously selected in Step 1 into the test fixtures in accordance with Figure 4. Then fill test fixtures with KOH and oxygen in the following manner:

Step 2B.1.

Vacuum fill fixture completely with KOH; then remove 16 cc of the fluid and close valve. Mount test fixture vertically into a fixture simulating the rotating manifold. Connect oxygen tank to valve and pressurize fixture to 50 psi, remove oxygen connection and vent the fixture to the atmosphere. Repeat this operation three times, closing the valve after the last venting operation. After the filling operation above, assemble test fixtures into the rotating pressure manifolds provided, and start the test cycle.

Step 3B - Sampling Test

At 10 day intervals, one specimen of each type will be removed from each of the three test fixtures. These specimens shall then be subjected to the physical testing, sectioning and evaluation as previously described in the Phase A testing.

Step 6

At the conclusion of all testing, the test data will be evaluated and incorporated into the final test report.

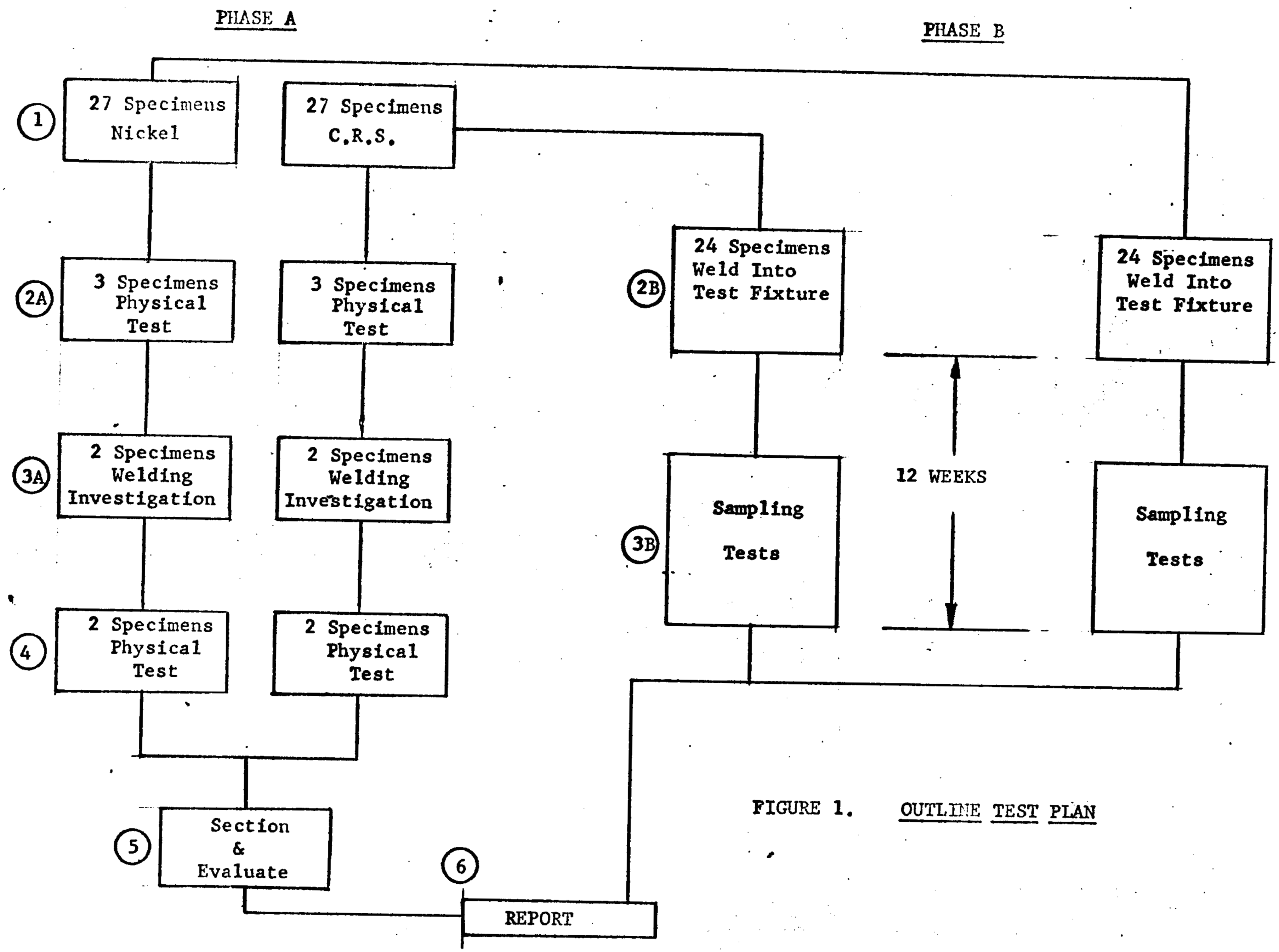

FIGURE 1. OUTLINE TEST PLAN

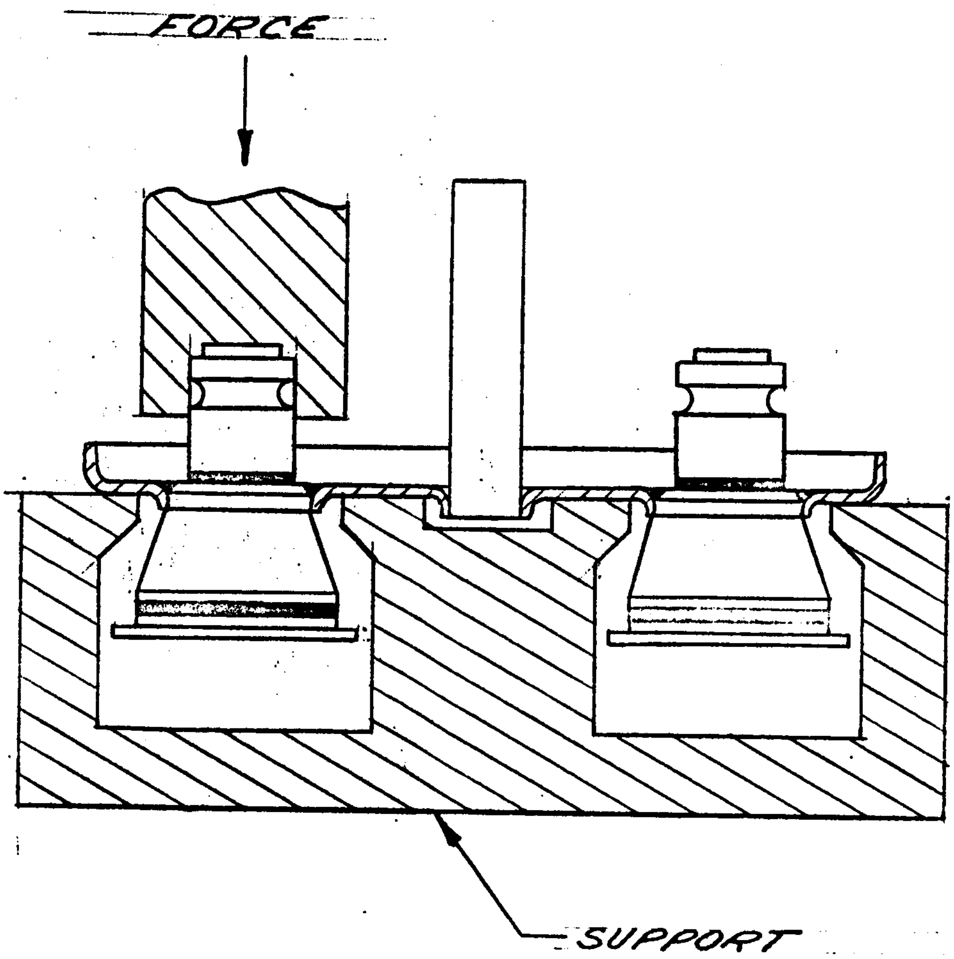

FIG. 2 FORCE vs. DEFECTION
TEST ARRANGEMENT

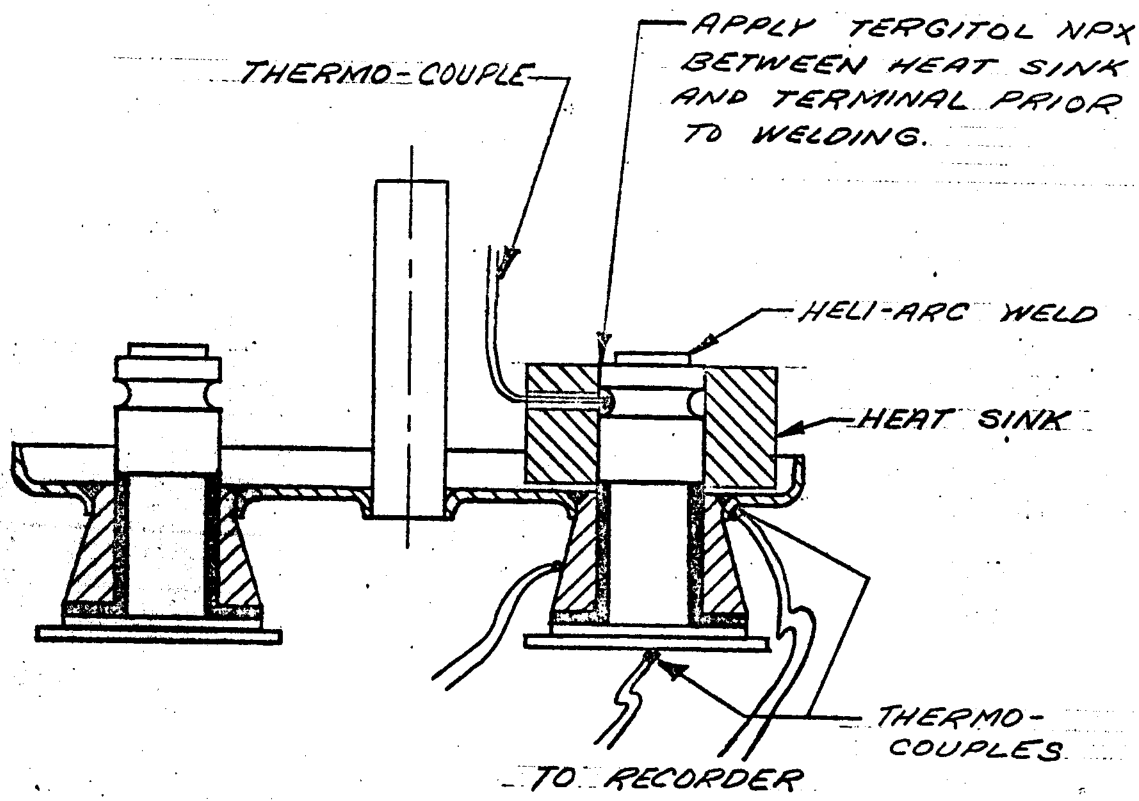

FIG. 3A HEADER WELDING INVESTIGATION ARRANGEMENT

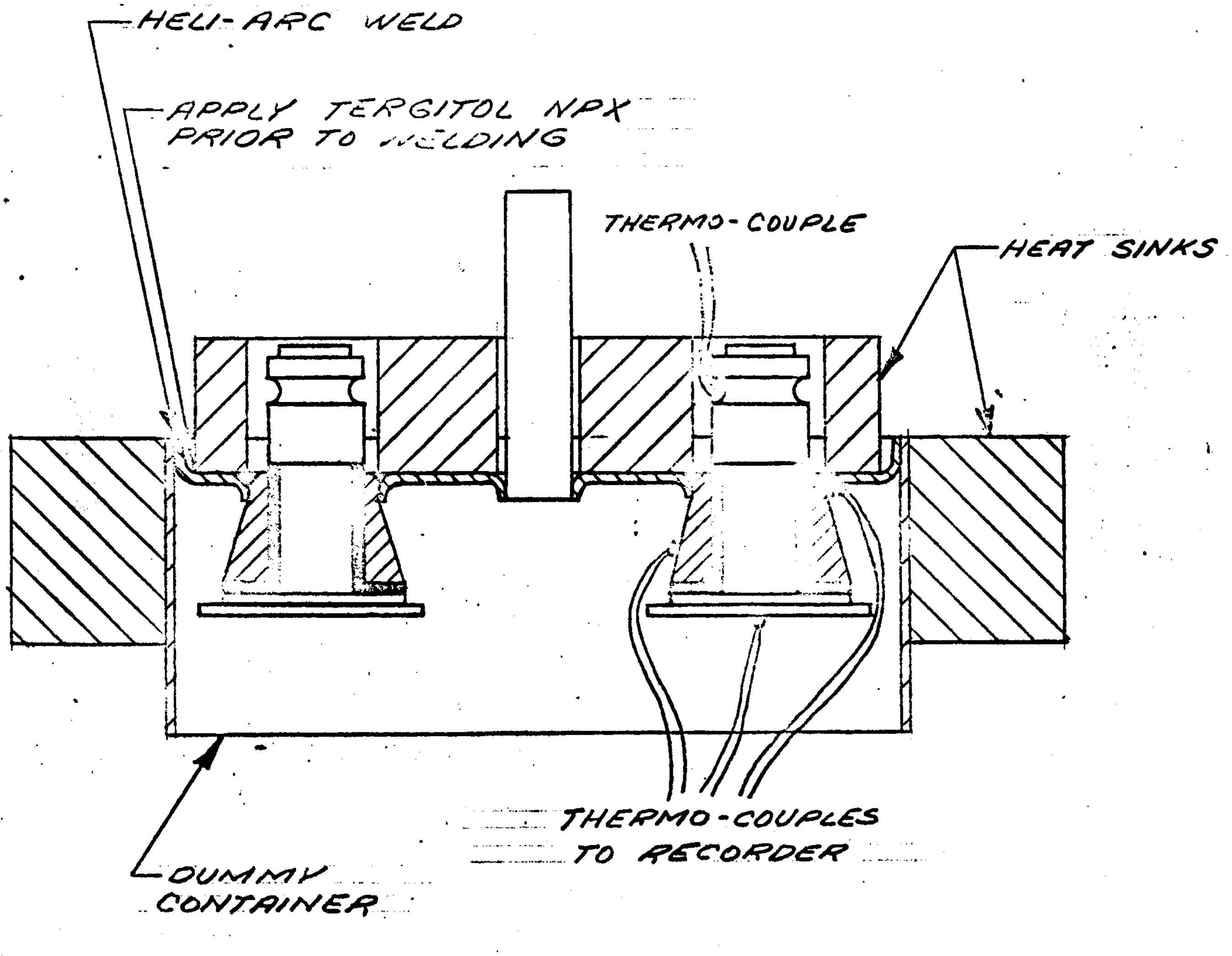

FIG. 3B HEADER WELDING INVESTIGATION ARRANGEMENT

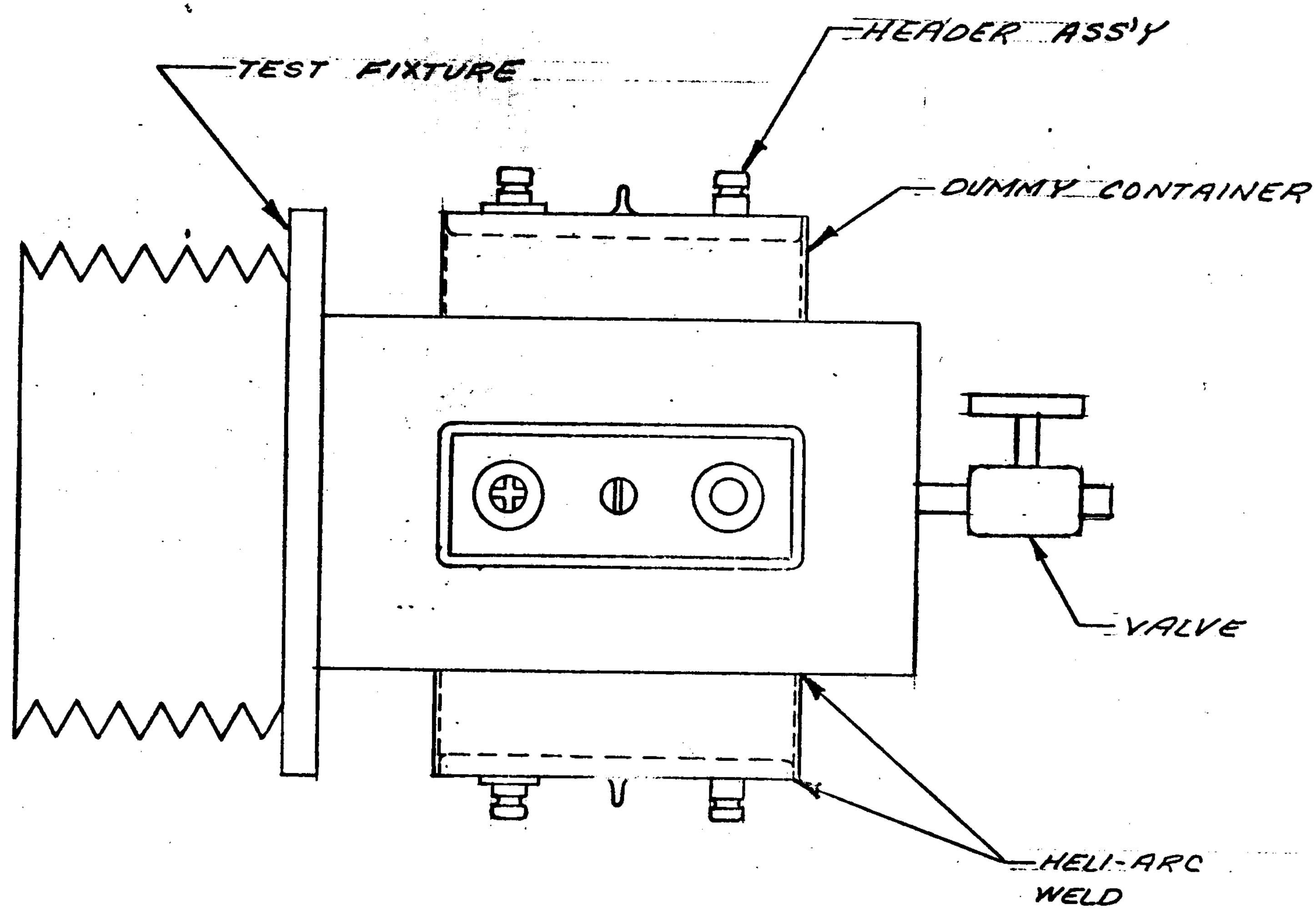

FIG 4 TEST FIXTURE